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Specification Document

1. Title of the Utility Model

Single Crystal Growth Apparatus

2. Scope of the Utility Model Claims

A single crystal growth apparatus equipped with a crucible for containing a melt liquid of a crystal raw material, a first heating means disposed at the periphery of the crucible for heating the melt, and a pulling means for pulling up the single crystal from the melt;

wherein the single crystal growth apparatus further comprises a second heating means disposed in a space formed by the crucible, the melt, and the pulled single crystal.

3. Detailed Description of the Utility Model

(Industrial Field of Use)

The present utility model relates to a single crystal growth apparatus equipped with a crucible for containing a melt liquid of a crystal raw material, a first heating means disposed at the periphery of the crucible for heating the melt, and a pulling means for pulling up the single crystal from the melt. The present utility model is used with advantage for growth of a rod shaped single crystal.

(Summary of the Utility Model)

According to the present utility model, a single crystal growth apparatus is equipped with a crucible for containing a melt liquid of a crystal raw material, a first heating means disposed at the periphery of the crucible for heating the melt, and a pulling means for pulling up the single crystal from the melt; and the single crystal growth apparatus further includes a second heating

means disposed in a space formed by the crucible, the melt, and the pulled single crystal. Growth of high quality single crystal by this means is possible at a high growth rate and with few crystal defects.

(Conventional Technology)

The Czochralski method (CZ method) has been conventionally used for pulling and growing silicon single crystals. According to the CZ method as shown in FIG. 4, the melt liquid of crystal raw material contained within a crucible 2, which is made of quartz and is provided within a crucible 1 made of graphite, is heated by a heater element 4 disposed so as to surround the crucible 1. During this heating, a rod shaped single crystal 6 grows at a seed crystal 5 from the melt liquid 3 due to pulling upward of the single crystal 6 by a chuck 7. During this crystal pulling, the crucibles 1 and 2 and the single crystal 6 are rotated in mutually opposite directions using a shaft 8 and the chuck 7, respectively, for example, at fixed rates. Also during this crystal pulling, the shaft 8 is used to raise the crucible 1 so as to maintain the heater element 4 at a fixed position relative to the liquid surface of the melt liquid 3.

Assuming that the solid-liquid interface between the single crystal 6 and the melt liquid 3 is flat and that there is no radial direction temperature gradient in the single crystal 6, the maximum pull rate V_{max} of the single crystal 6 obtained by this CZ method is given by the following formula.

$$V_{max} = \frac{k}{h \times \rho} \left(\frac{dT}{dx} \right)$$

Within the formula, k is the thermal conductivity coefficient of the single crystal 6, h is the heat of fusion of the single crystal 6, ρ is the density of the single crystal 6, and (dT/dx) is the temperature gradient within the solid phase (i.e. single crystal 6) at the solid-liquid interface. Also, x is the coordinate in the axial direction of the single crystal 6. In the above described formula, k, h, and ρ are fixed values determined by the substance, and thus (dT/dx) must be made large in order to obtain a large value for V_{max}. However, in the above described CZ method, the single crystal 6 is heated by radiant heating from the surface of the melt liquid 3, from the inner wall of the crucible 2, from the heater element 4, and the like. Therefore the above described (dT/dx) is reduced due to such radiant heating, and thus the obtained pull rate is small in practice.

Although this pull rate can be increased by overall lowering of the temperature of the heater element 4, this method is deficient in that a part 3a of the melt liquid 3 adjacent to the liquid surface of the melt liquid 3 and the crucible 2 may solidify due to temperature in the vicinity of the surface of the melt liquid 3 becoming cold at the peripheral part in comparison to the central part, and such solidification may become problematic for continued pulling of the single crystal 6. Therefore the maximum possible pull rate during continuous pulling of the single crystal 6 without any type of interference using the single crystal pulling apparatus shown in FIG. 4 has been about 1 mm per minute. However, since the above described solidification more readily occurs as the diameter of the single crystal 6 has become larger, further lowering of the pull rate has been necessary.

Unexamined Laid-open Patent Application No. S59-176420 is cited as a citation document mentioning conventional technology that relates to the present utility model. In this citation document, a single crystal growth apparatus is disclosed that includes a first heating

means that is capable of a high degree of heating of, among the regions of melt liquid within the crucible, the melt liquid part that is adjacent to both the melt liquid surface and the crucible.

(Problem to Be Solved by the Utility Model)

The object of the present utility model is to solve the above described problem and to provide a single crystal growth apparatus that solves the above described problems of the conventional single crystal growth apparatus.

(Means to Solve the Problem)

The single crystal growth apparatus according to the present utility model is a crystal growth apparatus equipped with a crucible for containing a melt liquid of a crystal raw material (e.g. the crucible 2 for containing a silicon melt liquid 3), a first heating means (e.g. the heater element 4) disposed at the periphery of the crucible for heating the melt, and a pulling means (e.g. a pulling shaft 19 and the chuck 7) for pulling up the single crystal from the melt; wherein the single crystal growth apparatus further includes a second heating means (e.g. heater element 16) disposed in a space (e.g. a space 15) formed by the crucible, the melt, and the pulled single crystal.

(Operation of the Utility Model)

Due to this configuration, among the regions of melt liquid within the crucible, effective heating is possible for the melt liquid part adjacent to the liquid surface of the melt liquid and the crucible.

(Example)

Figures will be cited below during explanation of an example of the single crystal pulling apparatus of the present utility model. Furthermore, in the below listed figures, parts which are the same as those of FIG. 4 will be assigned the same part numbers, and as may be required, the explanation of such parts may be omitted.

As shown in FIG. 1 and FIG. 2, in the single crystal growth apparatus of the present example in the same manner as the conventional single crystal growth apparatus shown in FIG. 4, the silicon melt liquid 3 is contained within the quartz crucible 2 disposed within the graphite crucible 1, and the graphite heater element 4 and an insulator element 9 are also provided so as to surround the above described crucible 1. Also, water cooling jackets 10a through 10c are provided to entirely surround these parts. In this water cooling jacket 10b, a window 11 is provided for observation of the pulled single crystal 6. At the bottom face of the water cooling jacket 10a, an exhaust pipe 12 is provided for venting of an inert gas (gas atmosphere) fed from above into the space between the water cooling jackets 10a through 10c. At the lower part of the crucible 1, a shaft 8 passing through an aperture 10a at the bottom face of the water cooling jacket 10a is provided for raising, lowering, and rotating the crucible 1. Also, a ring shaped plate 13 is fixed to the bottom tip of the heater element 4. At the lower part of this ring plate 13, raising-lowering shafts 14 passing through apertures 10e and 10f provided at the bottom face of the water cooling jacket 10a are provided for raising and lowering of the heater element 4.

However, in the space 15 formed by the crucible 2, the melt liquid 3, and the single crystal 6, a circular heater element 16 is provided in the vicinity of the liquid surface of the melt liquid 3. This heater element 16 is attached to the bottom face of the cylindrically shaped heat shield body 17 through a thermal insulation component (not illustrated). Furthermore, this heat

shield body 17 is configured so as to be capable of moving in the axial direction (i.e. vertical direction) so that the distance between the melt liquid 3 and the heater 16 can be changed by causing movement of this heat shield body 17. Further upward, a seed crystal 5 is held by the chuck 7 attached to the lower tip of the pulling shaft 18, and the rod shaped single crystal 6 grows from this seed crystal 5.

During growth of the single crystal 6 from the silicon melt liquid 3 at the seed crystal 5 using the single crystal growth apparatus configured in this manner, pulling of the single crystal 6 occurs while the crucibles 1 and 2 and the single crystal 6 are rotated, for example, in mutually opposite directions using the shaft 8 and the pulling shaft 18, respectively. Also during growth of the single crystal 6, the single crystal 6 is pulled up using a non-illustrated mechanism, and the crucibles 1 and 2 are raised so that the heater 4 is at a fixed position relative to the liquid surface of the melt liquid 3.

The above described example has the following advantages.

That is to say, the heater 16 is provided near the liquid surface of the melt liquid 3 within the space 15 formed by the crucible 2, the melt liquid 3, and the single crystal 6. Therefore effective and selective heating is possible of the vicinity of the liquid surface of the melt liquid by this heater element 16. Therefore, the differential between the temperature in the vicinity of the liquid surface of the melt liquid 3 and the maximum temperature within the melt liquid 3 can be lowered relative to the conventional technology. For this reason, even if temperature of the heater element 4 is lowered in order to increase the above described temperature gradient (dT/dx), solidification occurs with difficulty. Also, among the regions of the melt liquid 3, at the part 3a adjacent to the liquid surface of this melt liquid 3 and adjacent to the inner wall of the crucible 2, solidification occurs with difficulty due to the decrease of the above described temperature differential in comparison to the conventional technology, and thus the temperature of the heater element 4 can be lowered by the amount of this decrease of temperature differential. Therefore the pull rate of the single crystal 6 can be greatly increased (e.g. to 2.0 mm per minute) relative to the conventional technology. Moreover, growth of the single crystal 6 can be continued without any type of hindrance. As a result, productivity is high in comparison to the conventional technology, and thus the cost of growth of the single crystal 5 can be lowered.

Moreover, the density of stacking faults within the single crystal 6 obtained by growing the single crystal 6 at a high growth rate (i.e. about 2 mm per minute) in the above described manner is extremely low, and thus quality of the single crystal 6 is extremely high.

Furthermore, due to disposal of the heat shield body 17 surrounding the single crystal 6, it is possible to prevent heating of the single crystal 6 due to radiant heating from the heater elements 4 and 16, the melt liquid 3, and the crucible 2, and the like. Therefore, the temperature gradient (dT/dx) can be increased by a corresponding amount, and growth rate of the single crystal 6 can be increased by this means.

Furthermore, the single crystal growth apparatus can be constructed inexpensively due to the ability to simply provide the heater element 16 in the vicinity of the liquid surface of the melt liquid 3.

Although an example of the present utility model was explained previously, the present utility model is not limited by the above described example, and various types of modifications are possible based on the technical concepts of the present utility model. For example, in the above described example, the heater element 16 was attached to the bottom face of the heat shield body 17 to form a single unit. However, as may be required, the heater element 16 and the heat shield body 17 can be separately provided as shown in FIG. 3. Furthermore, item 19 within

FIG. 3 is a support rod for support of the heater element 16. Moreover, when there is no longer a need for heating the entire surface of the melt liquid 3 as in the above described example, among the regions of the melt liquid 3, the part 3a adjacent to the liquid surface of this melt liquid 3 and the crucible 3 can be selectively heated (e.g. by narrowing width of the heater element 16 while keeping outer diameter of the heater element 16 the same). Furthermore, a heat shield plate of the same shape as the lower face 17a of this heat shield body 17 can be provided rather than the cylindrically shaped heat shield body 17, and the heater element 16 can be attached to the lower face of this heat shield plate. Also as may be required, the distance between the heater element 16 and the liquid surface of the melt liquid 3 can be varied. Also as may be required, the heat shield body 17 may be cooled by cooling water and the like.

(Effect of the Utility Model)

According to the single crystal pulling apparatus according to the present utility model, the second heater element is disposed in the space formed by the crucible, the melt, and the pulled single crystal. Therefore effective heating is possible of, among regions in the melt liquid within the crucible, the melt liquid part adjacent to the liquid surface of the melt liquid and the crucible. Therefore the occurrence of solidification of the above describe part can be prevented even when heating temperature due to the first heating means is lowered. Therefore good quality single crystal can be grown with few crystal defects even at a high pull rate in comparison to the conventional technology.

4. Simple Description of Figures

FIG. 1 is a cross sectional diagram showing an example of the single crystal growth apparatus according to the present utility model. FIG. 2 is a magnified cross sectional drawing showing the essential parts of the single crystal growth apparatus shown in FIG. 1. FIG. 3 is a magnified cross sectional drawing, which is similar to FIG. 2, although showing a modified example of the present utility model. FIG. 4 is a cross sectional drawing of essential parts of a conventional single crystal growth apparatus using the CZ method.

The utilized numbering of the parts within the figures is listed as follows.

1, 2	...	crucible
3	...	melt
4, 16	...	heater element
6	...	single crystal
15	...	space
17	...	head shield body
18	...	pulling shaft

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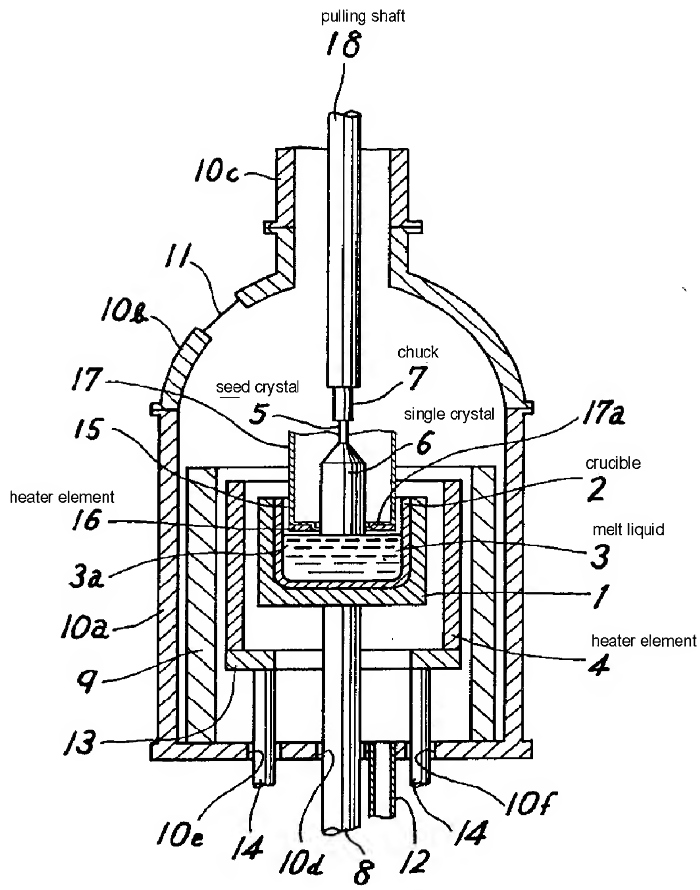
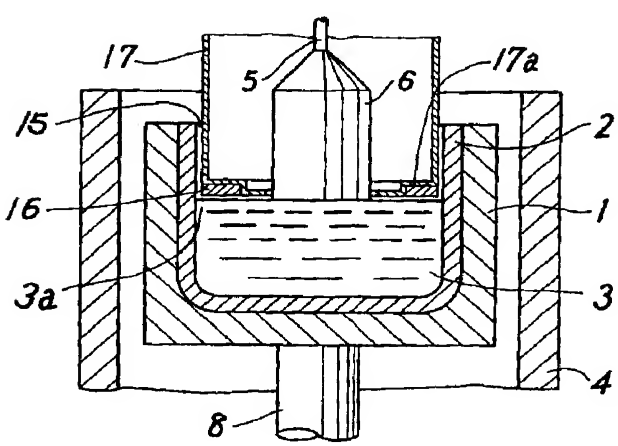
FIG. 1



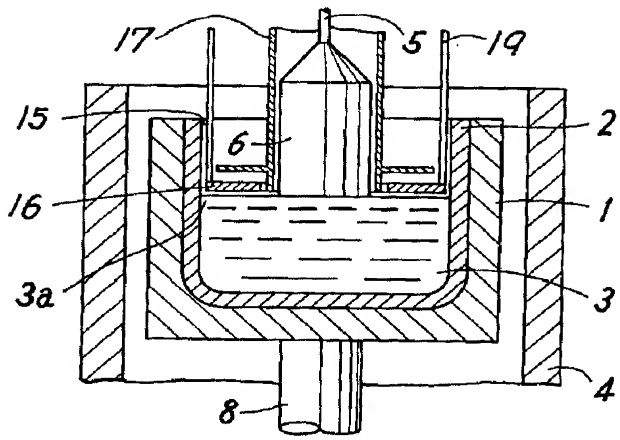
single crystal growth apparatus

FIG. 2



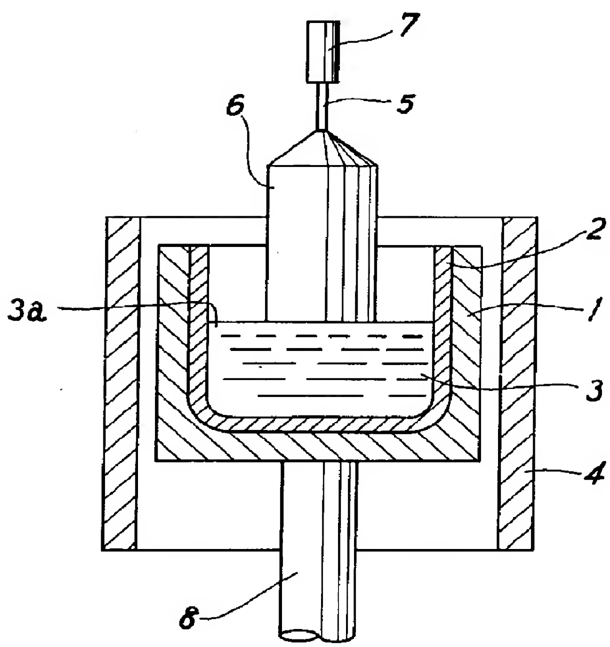
essential parts of single crystal growth apparatus

FIG. 3



essential parts of single crystal growth apparatus

FIG. 4



essential parts of the conventional single crystal growth apparatus